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PERFORMANCE STUDIES ON THE REVERSING VALVE INCORPORATED AIR-TO-WATER HEAT PUMP WITH HEAT STORAGE DEVICE

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ABSTRACT

In order to avoid the rapid on and off, the condition of partial load is maintained by the heat storage device. With Plate heat exchanger in the air to water heat pump, the heat storage device is for heating along with large variation of supply, defrosting time and return water temperature. A Water tank and an inner double pipe heat exchanger were included in the heat storage device. The heat storage device can able to reduce on and off times by utilizing the compressor in energy storage, as it consists of appendages and electric heater. In electric heater and electric storage, there is a shortage of heating during defrosting. Under partial load, it reduces on and off times by utilizing the compressor in heat storage device by four times per hour rather than six times per hour. The reduction in on and off times were exposed by the plate heat exchanger performance test. Also, there is a reduction of defrosting time in heat storage device with electric heater unit by 78s and 84s. While it reduces to 30.73ºC in plate heat exchanger, many steady running parameters either inlet heating water temperature of heat storage device or heat storage device with electric heater is about 33ºC. Thus, the enhancement in the unit performance in designed heat storage device is obtained. With air to water heat pumps, it is suitable for new projects.

KEYWORDS: Heat Storage Device, Water Tank, Air-to-Water Heat Pump & Valve

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Original Article

1. INTRODUCTION

By the applications over worldwide, air source heat pumps were found. This is possible by considering the benefits of environmental protection and energy saving. The world population is about 90% for heat pumps heating and cooling in the suitable region from the global point of view.

Since 1990's, In Central and South China, Space heating and Air Conditioning has been used by the air to water heat pumps for the production of hot water. The comparison of energy performance between air to water and water to water heat pump in the applications was obtained in Hong Kong [1]. However, by the application of case study, it is used at the swimming pools with no covering problem of the units in the subtropical region. About COP, the heat pumps are in the range of 1.5-2.4 was found. By discussing the production of hot water and the applications of solar heat pump with tank, solar heat pump is also a kind of air to water heat pump. In order to

ensure the stable hot water supply. The heat pump supplies equal energy to the solar water heater. But the performance of cooling and melting are not concerned [2]. By the heating performance of air to water heat pumps, the gas engine is driven by modelling and analysing. One-third of the total heat capacity in the gas engine driven by air to water heat pump is occupied by the waste heating [3]. As most of the air to water heat pump is driven by the electric driven, there is no waste heat to recover the frequent on and off should be under the partial load, to improve the performance of air to water heat pump. In the above paper, insufficient heating capacity was not mentioned [4].

There will be a formation of snow in the heat exchanger of air side surface during the winter in humid climates. Air to water heat pump is also a kind of air source heat pump. The snow is build up over the air side of the heat exchanger coils as it is wrapping. The thermal performance was reduced by air to water heat pump. In order to improve the heating efficiency of air to water heat pump, snow must be removed. The solution for a problem of air to water heat pumps is nothing but defrosting.

By the studies of some researchers, frosting and defrosting are the problems of air source heat pump. A solenoid bypass valve is get expands by reliving the problem of shutdown. By solenoid bypass, the process of defrosting gets speed-up. Though the process of defrosting was speed, the time for defrosting would not be shortened. Prestart s the method, utilized for an air to water heat pump to defrost on the reverse cycle [5]. Prestart s utilized, in order to prevent from the shutting down. In defrost dynamic characteristics, the discussing of normal start test and coil fan prestart is turned out, along with the results between the two modes. By evaporator controlled multi circuit air water heat pump, there would be very small difference in dynamics of system. This was investigated experimentally during the period of frosting. The irregular hunting occurs in fin and tube exchangers due to airflow misdistribution often in a medium heat pump. Rather than U-type, for small heat pump, V-type or W-type is used. In a medium heat pump, it is arranged by the heat exchanger. A similar model of the frosting process in a water heating unit was obtained. It is approves and developed by using the experimental data. This investigation includes the operational characteristics and the effects on the performance of the unit under frosting air-side heat exchanger [6].

When compared with the air to air heat pump, air to water heat pump have a large capacity. In the water side heat exchanger of the units, by adopting the compact plate of the heat exchanger, the water capacity of the system is decreased nowadays. Air to water heat pump is designed with the unit capacity, only for peak cooling load [7]. By controlling the constant frequency single compressor with on and off and adjusting the capacity, unit is always working at partial load conditions. Energy consumption intermittent operation is larger than the continuous control at the unit off state by comparison. Hence by compressing the high pressure, this system will reach the equilibrium state. In the starting period, the system will again rebuild. To overcome at the same time, heat transfer is under struggle [8]. It will take several minutes, to reach the steady state condition. In comparison, the capacity of cooling or heating is smaller at the steady conditions but the capacity power consumption is greater. Losses come into owing state and the working condition is mode not corresponds to the load from the environment, under the variable condition on-off losses, with the performance of the lower partial load [9].

We can able to solve the problem of frequent on and off under partial load, by utilizing this paper. At the same time of frosting with plate heat exchanger during insufficient heating capacity and large water temperature variation, the introduction of adopting the heat storage device and electric heater are obtained to solve the problem of frequent on and off.

2. DESCRIPTION OF THE HEAT STORAGE DEVICE

Double pipe heat exchanger is placed at the water-side, in the heat storage tank. This is illustrated in the figure 1. To the heat exchanger on the tank, the inlet and outlet of refrigerant connector is connected. Drain valve, vent valve and relief valve are the valves included in the tank. For water supply, the tank is equipped with electric heater. At the end of the tank, the inlet and outlet is fixed. When the pressure of the water in the system expands is larger than the set value, water is fully contact with double pipe heat exchanger from the vent valve exists the air in the tank to enhance the heat transfer effect. By discharging the water from the relief valve, this is obtained to reduce the pressure and to check the security system twice.

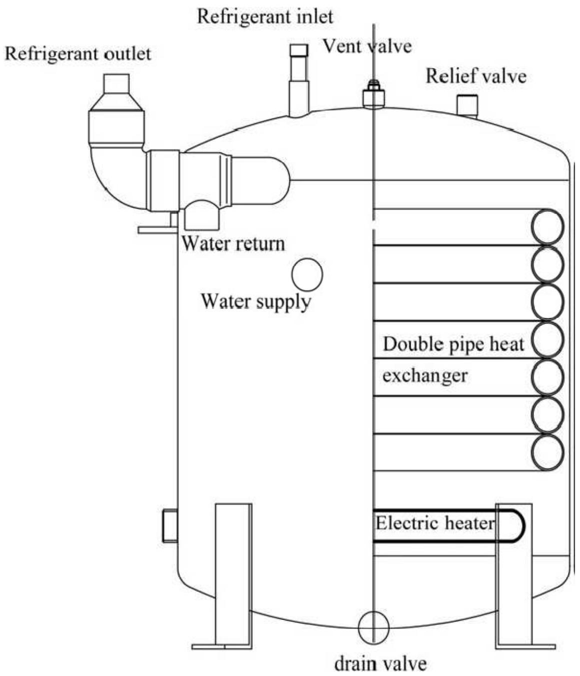

Figure 1: Construction of the Heat Storage Device

By changes in the water quality and drained through the drain valve, the impurities are generated, when the water system is cleaned. As it exchange heat with refrigerant along water through double pipe heat exchanger, water temperature can be reduced or increased along with the utilization of cold air conditioning in the heat exchanger. When the terminals out of full load, this is due to the large storage part of heat or cold in the capacity of the tank. During winter, the generation of heat in the electric heater provides the shortage of heat. Hence, the electric heater is turned on automatically, for setting the parameter. The shortage of heat during winter is due to cold surrounding. When there is a drop in the water temperature and worse melting during the frost or heating effect, water temperature heater, which is turned on with slight variation is reduced.

Table 1: Test Parameters of the Artificial Climate Chamber

	Temperature	Relative Humidity	Fluctuations Range of Temperature
Indoor(Cooling)	25.4	60	±0.56
Outdoor(Cooling)	34.9	60	±0.56
Indoor(Heating)	21.1	60	±0.56
Outdoor(Heating)	-7.5	75	±0.56

In order to obtain the counter current heat exchange, the refrigerant comes in the top copper pipe. This is extended to the bottom. Then, it will pass into the lower copper pipe of double pipe. It returns back to the top copper pipe of the compressor in the left side, after several passes of the heat exchanger. This is illustrated in the figure 2. Heat exchanger returns water which is coming from the left of the top outer steel pipe in the double pipe. The heat exchanger is in the middle of the steel and copper pipe, after several passes. Water is going directly from the steel pipe to the tank. From the pipe to the upper left of the tank, water comes finally as water supply. In the outer steel pipe and in the water tank, the angle iron and the heads are welded.

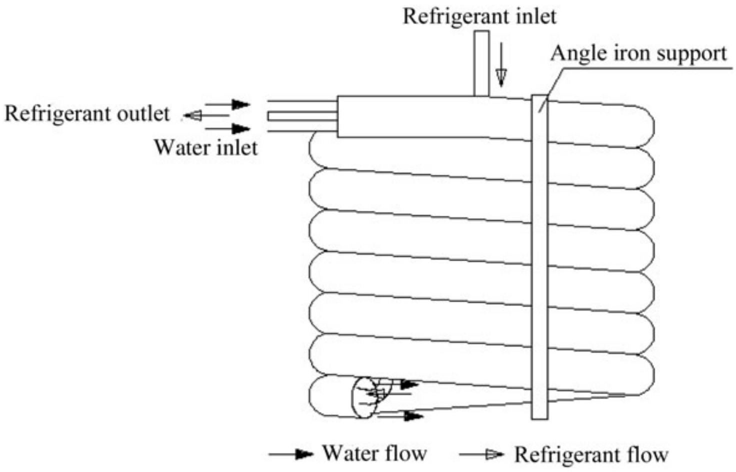

Figure 2: Refrigerant and Water Flowchart of the Double-Pipe Heat Exchanger

In the common air conditioning system of the heat exchanger and water tank, for the heat transfer, there is no wrapping in the out steel tube. To store heat for the system utility, the water has large density and thermal capacity.

3. TEST METHODOLOGY

In an air conditioning manufacturing company, the comparison test HLRS12.5 is made on air to water heat pump were carried out. Plate heat exchanger is the 1# unit water side heat exchanger. Heat storage device with double pipe heat exchanger is accompanied with 2# unit. In the artificial climate chamber, both the units were tested. The real fact simulation of national standard working condition was provided by testing in the artificial climate chamber. The testing is also provided to check the performance and measurement condition for unrepeatable condition. In the table 1, the test parameters are shown. The specifications of two tested heat pumps are listed in the table 2. An indoor test section, an outdoor test section; a test heat pump and a data acquisition system (DAS) are included in the heat pump-test apparatus. During testing and recording instrument, DAS automatically saves and gathers the experimental data. There are 224 channels in presence. Within 6s, the channels can scan rapidly. During experiments, all the temperature sensors and pressure sensors are calibrated to reduce all the uncertainties. Accuracies and tolerance of the sensors were tabulated in the table 3# to record the electrical power input. Here, there is the utilization of ME4zrt power measurement.

Table 2: Performance of the Test Unit

	Plate Heat Exchanger Unit (1#)	Units with Heat Storage Device (2#)
Nominal cooling capacity(kW)	12.5	12.5
Nominal heating capacity(kW)	15	15
Rated Power	4.53	4.53
Scroll compressor input power (kW)	3.98	3.98

Table 2: Contd.,		
Electrical power input(kW)	0	2
Fin heat exchanger	High efficiency copper tube bunched aluminum fins Plate heat exchanger	High efficiency copper tube bunched aluminum fins
Water-side heat exchanger	TDEX4	Double-pipe heat exchanger TDEX4
Thermal expansion valve	3.8	4.6
Refrigerant charge R22 (kg)	105.4	70.17

The artificial climate chamber can able to maintain and tackle the environmental temperature and room temperature within 0.3ºC, during stable state operation. Pressure sensor is used to detect, for compressor pressure measurement. By the particular sensors, the water temperature and return temperature were measured.

Table 3: Accuracies and Tolerance of the Sensors

	Type	Measuring Range	Accuracies	Tolerance
Thermocouple	TX-GA-W	250 to 2308C	+0.2	20.1 to 0.18C
Pressure sensor	MPM480	0 to 3 MPa	0.25	-5 to5kPa
Power meter	WT130	0 to 15 kW	+1%	-4to4 W

The methodology, which is preferred for the removal of air to water heat pump is Reverse Cycle Defrost. Reverse Cycle Defrost is the most common methodology. It runs in the cooling mode, initially. When the defrosting is completed, heat pump is switched by four way reversing valve. At the defrosting initial stage, it produces low pressure and comes back to the normal operation.

In the same artificial climate chamber, under the defrosting condition, unit 1# with plate heat exchanger, unit 2# with heat storage device of a non-enabled electric heater and unit 3# with heat storage device of an enabled electric heater were tested.

4. RESULTS AND DISCUSSIONS

4.1. Cooling Performance Test Results

It took 4min and 12s for supply in 1# unit's supply and the water temperature return to reach 7ºC and 12ºC respectively. This is illustrated in the figure 3. It took 8min and 18s for the temperature in 2# unit's supply to reach 7ºC and 12ºC respectively. This is illustrated in the figure 4. On and off four times were from 10.06.01 to 11.05.07 am and from 14.11.53 to 15.15.14 pm for 1# unit and 2# unit respectively. In 1# unit, the water flow resistance was 105.4 Kpa. In 2# unit, the water flow resistance was 70.17 Kpa. At the time of rest, the water flow resistance of 1# unit is greater than the water flow resistance of 2# unit. i.e., 105.4 Kpa> 70.17 Kpa. When the unit with the heat storage reduces the on and off times, the resistance is not increased under partial load.

4.2. Defrosting Results and Discussions

Under the defrosting conditions, the suction pressure, supply temperature and return water temperature were obtained due to DAS unit discharge. This is illustrated in the figure 5-8. During defrosting, the extreme values of system parameters is listed in the table 4. During the test, by observing the discharge, suction pressure, supply temperature and return water temperature, conclusion could be made.

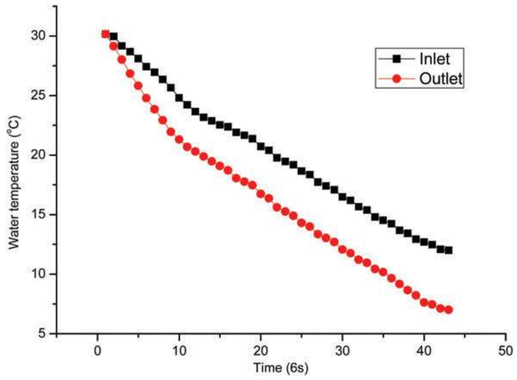

Figure 3: Water Temperature Variation of the 1# Unit when Cooling

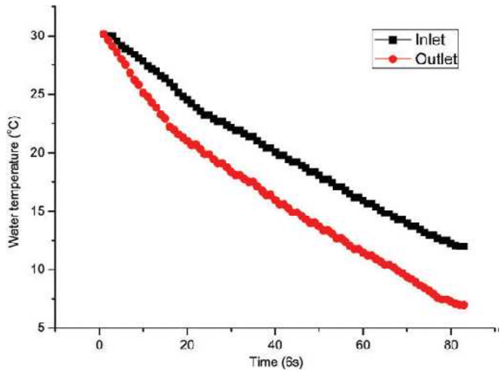

Figure 4: Water Temperature Variation of the 2# Unit when Cooling

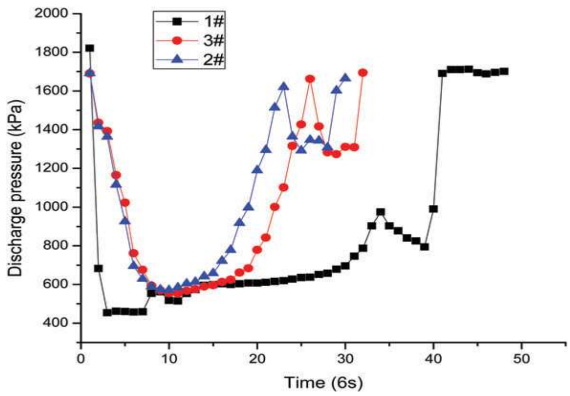

Figure 5: Comparison of Discharge Pressure Variation During Defrosting

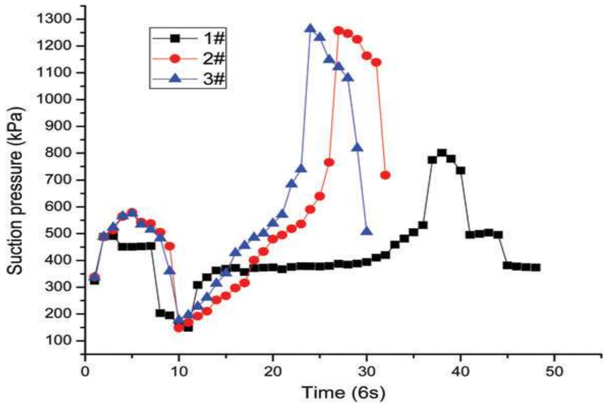

Figure 6: Comparison of Suction Pressure Variation During Defrosting

- The three system were running under in the steady state at the period of starting by reversing the four way reversing valve it discharge the suction pressure of the system and had a slight variation in temperatures. 3# unit rapidly in favour of defrost process in discharge and suction pressure and it shortened the defrost time which owing to the much larger openness of the thermal expansion valve and higher refrigerant flow rate. To avoid the low pressure protection the suction is much quicker and impact in the heat system. 2# unit is slightly worse than the 3#unit, variation tendency of discharge and suction pressure is similar. Due to lagging behind in the defrosting time discharge and suction pressure in the system is increased slowly. It had a poor defrosting effect of low suction pressure and speed in the 1# unit.

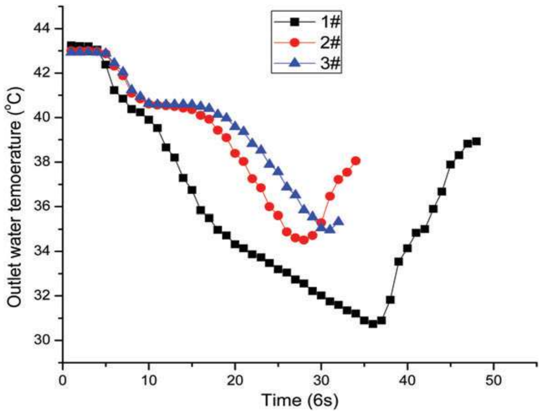

Figure 7: Comparison of Return Water Temperature Variation During Defrosting

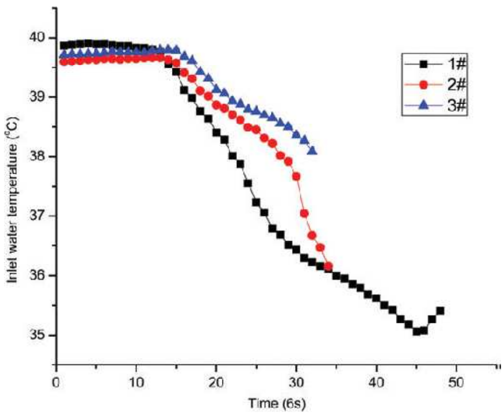

Figure 8: Comparison of Supply Water Temperature Variation During Defrosting

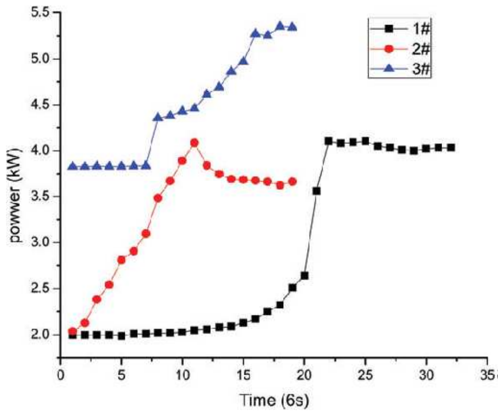

Figure 9: Comparison of Power Variation During Defrosting

- During the defrosting operation the refrigerant of 2# and 3# it obtain heat from the heat storage device simultaneously in the 3# unit started to increase the defrost heat source to speed up the effect of defrost by the electric heater, for the process of defrosting the temperature of the unit is dropped down by supplying the heat to the water but was still about 35℃. The reduction temperature of the system to 30.73℃ at 1# from inlet cold water, which caused large temperature variation.
- The defrosting time of 1#, 2#, 3# unit is 192, 114 and 108 s respectively. Apparently 2#, 3# units have relatively shorter defrosting time and prolonged heating time, which enhance the operation performance of the unit.
- In rapid input power versus the time is the electric energy consumption during the process of defrosting. Consumption of electric energy depends on the process of defrosting as shown in the figure 9, in order to obtaining by the DAS and under the defrost condition of power unit. Comparing to the 1#and 2# is smaller than the3# due to operation in electric heater simultaneously 2# consume minimum energy of defrosting due to heat storage. During defrosting course the energy consumption of 3# unit is 204 KJ which is more than 2# unit of the electric heater.
- Test door air temperature is -7.5℃of in winter and 34.9℃ of in summer during the test. In practical project the outdoor temperature is higher in winter and lower in summer, the unit has evaporating temperature and lower condensing temperature, the performance of the heat pump in term of COP is much higher and also better in aspects of defrosting and reduces the on and off times in an hour.

5. CONCLUSIONS

- To reduce the on and off times in compressor with the temperature variation in air to water heat pump in a heat storage device by storing a cooling capacity which can save energy and prolong the life.
- The heat storage device with electric heater is enhance the heating effect of the unit in winter and withstand from the defect of air to water heat pump frost. In the heat storage device there is a presence of heat stored from the electric heater during defrosting.

In the heat pump the pressure of air to water with heat storage device rises rapidly and temperature variation is small during defrosting. It has high reliability and stability good defrosting effect and short defrosting time.

REFERENCES

1. *Nishimura T. Heat pumps-status and trends in Asia and the Pacific. Int J Refrig 2002;25:405–13.*
2. *Joseph CL, Wilco W. Chan Energy performance of air-to-water and water-to-water heat pumps in hotel applications. Energy Convers Manage 2003;44:1625–31.*
3. *Li H, Yang H. Study on performance of solar assisted air source heat pump systems for hot water production in Hong Kong. Appl Energ 2010;87:2818–25.*
4. *Varma, S. Understanding the prevalence and effect of quality of worklife in the pumps industry.*
5. *Zhang RR, Lu XS, Li SZ, et al. Analysis on the heating performance of a gas engine driven air to water heat pump based on a steady-state model. Energy Convers Manage 2005;46:1714–30.*

6. *Ding Y, Ma G, Yi J. Experiment investigation of reverse cycle defrosting methods on air source heat pump with TXV as the throttle regulator. Int J Refrig 2004;27:671–8.*

7. *Huang D, Yuan XL, Zhang XQ, et al. Effect of fan-starting methods on the reverse-cycle defrost performance of an air-source heat pump. Int J Refrig 2004;27:107–12.*

8. *Huang D, He ZL, Yuan XL. Dynamic characteristics of an air-to-water heat pump under frosting/defrosting conditions. Appl Therm Eng 2007;27:1996–2002.*

9. *Sunitha, K. R., & Jacob, B. (2015). Dynamic Buckling Of Steel Water Tank Under Seismic Loading. International Journal of Civil Engineering (IJCE), 4(6), 81-90.*

10. *Yao Y, Jiang Y, Deng S, et al. A study on the performance of the airside heat exchanger under frosting in an air source heat pump water heater/chiller unit. Int J Heat Mass Transfer 2004;47:3745–56.*

11. *Xiang H. Air-Conditioning Engineering. Mechanical Industry Press, 2006, 307–13.*

12. *Moffat RJ. Describing the uncertainties in experimental results. Exp Thermal Fluid Sci 1988;1:3–17.*